1,002,642

PATENT SPECIFICATION

DRAWINGS ATTACHED

1,002,642

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Date of filing Complete Specification: Sept. 12, 1962.

Application Date: Sept. 26, 1961. *No. 34508/61.*

Complete Specification Published: Aug. 25, 1965.

Index at acceptance:—F1 F(1B5D, 2F, 2X10)

Int. Cl.:—F 01 c, F 05 g

COMPLETE SPECIFICATION

Improvements in Helical Screw Pumps

We, MONO PUMPS AFRICA (PROPRIETARY) LIMITED, a South African Company, of 32, Wendell Street, Lakeview, Johannesburg, Transvaal Province, Republic of South Africa, do hereby declare this invention for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention concerns improvements in helical screw pumps. A pump of this type previously made by us comprises an inner member having an external (male) helical thread, and an outer member having an internal (female) double start thread, the cross-section of the inner member at any point along its length being circular and the cross-section of the space within the outer member at any point along its length being a figure bounded by two semicircles, each of a diameter equal to the diameter of the circle of cross-section of the inner member, and two common tangents to the semicircles. The inner member is mounted rotatably within the outer members. The centres of the circles of successive cross-sections of the inner member lie along a helix, the axis of which is the axis of the inner member and the centres of the circles of cross-section of the inner member are eccentric to the axis of the inner member the eccentricity being the radius of the helix. If the inner member is rotated about its axis whilst meshing within the outer member, the axis of the inner member describes a small circle, of radius equal to the eccentricity, in a direction opposite to the rotation of the inner member and the circular cross-section at any point along the length of the inner members moves in a straight line path back and forth across the corresponding section of the outer member.

In one form of pump of the type referred to, the outer member is fixedly mounted and the inner member is coupled to a rotary driving shaft by a universal joint, whilst in another form, the universal joint is omitted, the inner member being mounted solely for rotation about its axis, and the outer member is mounted so as to be movable in a direction orbital to its axis so that the correct relative movement between the members is obtained.

The term "pump" is intended to cover not only conventional pumps, but also compressors, rotary engines and fluid motors.

It is an object of this invention to provide a pump of this type but having a plural-start grooved inner member and co-operating outer member. We have found that the relative dimensions of the parts of the pump are critical.

According to the invention, there is provided a helical screw pump comprising an outer member and an inner member mounted sealingly within the outer member, the two members being mounted for relative rotation, the outer member having at least four internal helical grooves and the inner member having one less helical lobe, the said grooves being defined in any cross-section through the outer member perpendicular to the axis thereof by part-circular lobe arcs which have equal radii in a range from zero to a finite value, and the ratio of the diameter (D) of the circle hereinafter referred to as the "outer member scroll circle" through the radial centres of the lobe arcs in any cross-section through the outer member at right angles to the axis thereof to the eccentricity (E) of the inner member, the eccentricity being the distance that the inner member axis is offset from the outer member axis, being substantially equal to

$$\frac{16 \sin \frac{180^\circ n - 540^\circ}{2n(n-1)} \cdot \cos \frac{540^\circ}{2n} \cdot \sin \frac{360^\circ}{2(n-1)}}{\left(1 - \cos \frac{180^\circ}{n}\right) \cdot \left(1 - \cos \frac{180^\circ n - 540^\circ}{n-1}\right) - 4 \sin^2 \frac{180^\circ n - 540^\circ}{2n(n-1)}} \quad \ldots\ldots (1)$$

where n is the number of grooves in the outer member in order that the two members should rotate relatively to one another without jamming and without sealing contact between the said lobes and grooves being broken during rotation.

The precise shapes which the two members must have are also completely determined for any specific value of the radius of the describing arcs of the grooves of the outer member.

The cross-section of the space within the outer member at any point along its length may be constant in shape, although varying in angular orientation about the outer member axis, the cross-section of the space being defined by a figure the periphery of which may comprise lobe arcs having equal radii of a finite value and described from centres (hereinafter called " lobe centres ") within the cross-section and equiangularly spaced circumferentially on the outer member scroll circle, and a corresponding number of intermediate part-circular arcs (hereinafter called " blending arcs ") joining the lobe arcs, the junctions of the lobe arcs and blending arcs being at positions of common tangents to the arcs, and described from centres outside the cross-section and equiangularly spaced around a circle concentric with the outer member scroll circle at positions angularly intermediate the lobe centres. The cross-section of the inner member at any point along its length may be constant in shape, although varying in angular orientation about its axis, the cross-section being defined by a figure comprising the appropriate number of identical part-circular lobe arcs, i.e. one less to be are than that of the outer member, but of the same radius as the outer member lobe arcs, described from inner member lobe centres within the inner member cross-section and equiangularly spaced around a circle (referred to as the " inner member scroll circle ") having its centre on the axis of the inner member, and a corresponding number of part-circular inner member blending arcs joining the inner member lobe arcs, the junctions of the inner member lobe arcs and the inner member blending arcs being at positions of common tangents to the arcs, described from centres outside the inner member cross-section and equiangularly spaced around a circle concentric with the inner member scroll circle through the inner member lobe centres at positions angularly intermediate the latter. The inner member scroll circle may have a diameter which is equal to the outer member scroll circle diameter (*D*) less twice the eccentricity (*E*) (i.e. inner member scroll diameter = −2E), and the distance of the describing centres of the blending arcs of the outer member from the outer member axis being substantially equal to

$$\frac{2E\,(D-2E)}{4E - D\left(1 - \cos \frac{180^\circ}{n}\right)} \quad \ldots\ldots (2)$$

where n has the same significance as before. The distance of the describing centres of the inner member blending arcs from the inner member axis may be substantially equal to

$$\frac{2E\,(D-4E)}{6E - D + (D-2E) \cos \frac{180^\circ}{n-1}} \quad \ldots\ldots (3)$$

where n again has the same significance as before.

Where the outer member and inner member are made of a substantially non-

resilient material, e.g. steel or brass, the values of $\frac{D}{E}$ and the distances of the centres of the blending arcs of the outer member and inner member from the respective centres of the latter should be given exactly by the expressions in the above statement. Where, however, the outer member is formed of a resilient material, e.g. natural or synthetic rubber, it will be appreciated that these values may approximate to those given by these expressions.

The cross-sectional shapes of the outer member and inner member of a pump according to this invention for a given number of outer member grooves may be determined by specifying the outer member scroll diameter or the eccentricity, (i.e. D or E) and the radius of the outer member (and inner member) lobe arcs. This lobe arc radius may theoretically be in a range from zero, when the lengths of the outer member and inner member lobe arcs are zero and the internal form of the outer member and external form of the inner member are defined solely by the blending arcs, to a value equal to the distance between the lobe centre and the adjacent blending arc centre at which the lengths of the blending arcs become zero and the internal form of the outer member and external form of the inner member are defined solely by the lobe arcs. In practice, values within this range but away from the extreme limits are preferably used.

Although in the pump according to this invention the outer member may be fixed against rotation and the inner member may be rotated by a Cardan shaft or from any rotatable driving shaft *via* a universal joint, the inner member and outer member are both symmetrical about their respective axes and the only eccentric motion is a rotation of the axis of the inner member about the axis of the outer member in a direction opposite to the direction of rotation of the inner member about its own axis so that the use of a universal joint may be dispensed with, the inner member being mounted solely for rotation about its axis, and the outer member allowed to rotate freely about its axis so that there are no out-of-balance forces. The outer member will in this case be driven by the inner member but will rotate at a speed slower in the ratio $\frac{n-1}{n}$.

In order that this invention may more readily be understood, reference will now be made by way of example to the accompanying drawings in which:—

Figure 1 illustrates diagrammatically a cross-section through a pump according to this invention and comprising an outer member having four grooves and a rotor having three lobes, this pump being the theoretically basic form in which the radius of the lobe arc is zero and the internal form of the outer member and external form of the inner member are defined solely by the blending arcs;

Figure 2 illustrates diagrammatically a cross-section through a pump of the form of Figure 1 and having the same scroll diameter and eccentricity, but having a finite lobe arc radius;

Figure 3 illustrates diagrammatically a cross-section through a pump according to this invention of the theoretically basic form comprising an outer member having five grooves and an inner member having four lobes;

Figure 4 shows diagrammatically a longitudinal section of a pump of this type;

Figure 5 shows diagrammatically a longitudinal section of a pump with rotatably mounted outer member.

Referring to Figure 1, the references 10, 12, 14 and 16 represent the centres of the outer member lobe arcs which in this basic form have a radius equal to zero. These centres lie at equiangularly spaced positions around a circle 18 which we term the " outer members scroll circle ", the centre 20 of which is on the axis of the outer member and the diameter of which is D. The outer member lobe arcs, in this case the points 10, 12, 14 and 16, are joined as shown by part-circular blending arcs 22, 24, 26 and 28.

The outer member 30 has helical grooves 32 with which helical lobes 34 of inner member 36 co-operate. The inner member is mounted to rotate about its axis sealingly within the outer member, and its axis is offset from the axis of the outer member by a distance E, the eccentricity of the inner member. Thus, the centre 38 of the cross-section of the inner member is spaced from the centre 20 by the distance E. The centres of the inner member lobe arcs, which like the outer member lobe arcs have a zero radius, are represented by the points 40, 42 and 44 and are joined by part-circular inner member blending arcs 46, 48 and 50.

As previously mentioned the ratio $\frac{D}{E}$ is given by expression (1). When $n=4$, this expression becomes

$$\frac{D}{E} = \frac{16 \sin \frac{15^\circ}{2} \cos \frac{135^\circ}{2} \sin 60^\circ}{(1-\cos 45^\circ)(1-\cos 60^\circ) - 4 \sin^2 \frac{15^\circ}{2}} \quad \ldots\ldots (4)$$

The distance of the describing centres of the outer member blending arcs 22, 24, 26 and 28 from the centre 20 must be equal, or substantially equal, to the value given by expression (2). When $n=4$, this expression becomes

$$\frac{2E\,(D-2E)}{4E-D\,(1-\cos 45^\circ)} \quad \ldots\ldots (5)$$

In Figure 1, the describing centre of the outer member blending arc 22 is indicated at 52 so that the distance between centre 52 and centre 20 is equal, or substantially equal to the value given by expression (5). The distance between the outer member scroll circle centre 20 and the point, indicated at 54, where the line between centre 20 and centre 52 intersects the blending arc 22 is $\frac{D}{2} - 2E$

The distance of the describing centres of the inner member blending arcs 46, 48 and 50 from the centre 38 must be equal, or substantially equal, to the value given by expression (3). When $n=4$, this expression becomes

$$\frac{2E\,(D-4E)}{6E-D+(D-2E)\cos 60^\circ} \quad \ldots\ldots (6)$$

In Figure 1, the describing centre of the inner member blending arc 50 is indicated at 56 so that the distance between centre 56 and centre 38 is equal, or substantially equal, to the value given by expression (6). The distance between the point, indicated at 58, where the line between centre 38 and centre 56 intersects the blending arc 50 and the point, indicated at 60, where such line intersects the inner member scroll circle 62 through points 40, 42 and 44 on centre 38, is $2E$.

Figure 2 illustrates a cross-section of a pump of the same form as that shown in Figure 1 and having an identical scroll circle, but in which the outer member and inner member lobe arcs have a finite radius. The points on Figure 2 corresponding with those of Figure 1 are indicated by the same reference numerals. It will be seen that the outer member has four identical part-circular lobe arcs 64, 66, 68 and 70 described about the centres 10, 12, 14 and 16 on the outer member scroll circle 18 and four part-circular blending arcs 72, 74, 76 and 78 described from the same centres as the arcs 22, 24, 26 and 28 of Figure 1. Thus arc 72 is described from the centre 52 a distance from centre 20 equal, or substantially equal, to the value given by expression (5). The junctions of the blending arcs 72, 74, 76 and 78 and lobe arcs 64, 66, 68 and 70 are at the points where the adjoining arcs have common tangents.

Similarly, (still referring to Figure 2), the inner member 36 has three identical part-circular lobe arcs 80, 82 and 84 of the same radius as the outer member lobe arcs and described about the centres 40, 42 and 44 and three part-circular blending arcs 86, 88 and 90 described from the same centres as the arcs 46, 48 and 50 of Figure 1. Thus arc 90 is described from the centre 56 a distance from centre 38 equal, or substantially equal, to the value given by expression (6). The junctions of the blending arcs 86, 88 and 90 with the lobe arcs 80, 82 and 84 are at the points where the adjoining arcs have common tangents.

It will be appreciated that a variety of pumps of the form of Figures 1 and 2

can be made having the same outer member scroll circle by varying the lobe arc radius. In each case the blending arcs will be described from the same centres. The limiting value for the lobe arc radius is given by the distance between the centre 10 and the centre 52 because then the blending arc radius becomes zero and the outer member form is described solely by the lobe arcs. Similarly, a variety of similar pumps can be made by varying the diameter of the scroll circle 18.

A further variation may be made by varying *n* the number of grooves of the outer member. Figure 3 shows the theoretically basic form of a pump according to this invention in which the outer member 30 has five grooves and the inner member 36 has four lobes.

Referring to this Figure, the reference 92, 94, 96, 98, and 100 represent the five centres of the outer member lobe arcs which in this basic form have zero radius. These centres lie at equiangularly spaced positions around the scroll circle 102, the centre of which is indicated by the reference 104 and the diameter of which is *D*. The points 92, 94, 96, 98 and 100 are joined by part circular blending arcs 106, 108, 110, 112 and 114.

The inner member 36 located within the outer member 30 has its axis offset from the axis of the outer member, i.e. the centre 116 of the inner member cross-section illustrated, is a distance *E* from the centre 104. References 118, 120, 122, and 124 represent the four centres of the inner member lobe arcs which in this basic form have zero radius. These centres lie at equiangular positions around the centre 116 and are joined by part-circular blending arcs 126, 128, 130 and 132.

When $n = 5$, expression (1) becomes

$$\frac{D}{E} = \frac{16 \text{ Sin } 9^\circ \text{ Cos } 54^\circ \text{ Sin } 45^\circ}{1 - \text{Cos } 36^\circ - 4 \text{ Sin}^2 \text{ } 9^\circ} \qquad \ldots\ldots (7)$$

Again, the distance of the describing centres of the outer member blending arcs 106, 108, 110, 112 and 114 from the centre 104 must be equal, or substantially equal, to the value given by expression (2). When $n = 5$, this expression becomes

$$\frac{2E\ (D - 2E)}{4E - D\ (1 - \text{Cos } 36^\circ)} \qquad \ldots\ldots (8)$$

In Figure 3, the describing centre of the outer member blending arc 106 is indicated at 134 so that the distance between centre 134 and centre 104 is given by expression (8). As before, the distance from the scroll circle centre, in this case 104, to the point of intersection, indicated by the reference 136, of the line between centres 134 and 104 with the blending arc 106 is $\frac{D}{2} - 2E$.

The distance of the describing centres of the inner member blending arcs 126, 128, 130 and 132 from the centre 116 must be equal, or substantially equal, to the value given by expression (3). When $n = 5$, this expression becomes

$$\frac{2E\ (D - 4E)}{6E - D + (D - 2E)\ \text{Cos } 45^\circ} \qquad \ldots\ldots (9)$$

In Figure 3, the describing centre of the inner member blending arcs 132 is indicated at 138 so that the distance between centre 138 and centre 116 is given by expression (9). As before, the distance between the point, indicated at 140, where the line between centre 116 and centre 138 intersects the blending arc 132 and the point, indicated at 142, where such line intersects the inner member scroll circle 144 through points 118, 120, 122 and 124 on centre 116 is $2E$. That is the distance between points 140 and 142 is $2E$.

As in the case of the form of pump shown in Figures 1 and 2 an infinite variety of pumps of the form of Figure 3 may be produced by varying the outer member and inner member lobe arc radius from zero as shown in Figure 3 to the maximum

value which equals the distance between point 92 and point 134, the blending arcs in each case being described from the same centres as the blending arcs 106 to 114, and 126 to 132 of Figure 3. Further variation may be produced by varying the diameter of the outer member scroll circle 102.

As previously stated, pumps in which the lobe arc radius differ from the extremes of its possible values are preferred. Figure 2 shows cross-sectional shapes of a suitable intermediate form of pump having an outer member provided with four grooves and an inner member provided with three lobes. A form suitable for many uses, may be that in which the outer member blending arcs are tangential to the outer member scroll circle 18 and in which the inner member blending arcs are tangential to the inner member scroll circle 62 through the inner member lobe arc centres 40, 42, and 44.

It will be appreciated from the foregoing description how pumps having outer members provided with six or more grooves may be constructed on the same principle as illustrated in connection with outer members having four and five grooves. Although a pump can be made in accordance with this invention with an outer member having any number of grooves greater than four, it seems that particularly useful forms of pump will have outer members having five, six, or seven grooves.

Referring to Figure 4, there is shown diagrammatically a helical screw pump having an internally helically grooved outer member 30, and an externally lobed inner member 36 within the outer member. The direction of flow of fluid through the pump axially, will depend upon the direction of rotation of the pump, whether openings 150 and 152 are to be inlet and outlet openings, or vice versa. The inner member 36 has a driving shaft 37 whereby rotary power may be applied to the inner member.

Referring to Figure 5, there are shown an inner member 36 mounted to rotate in fixed bearings 200 about its axis 202, and within an outer member 30 mounted to rotate on fixed bearings 204, about its axis 206, which is eccentric to the inner member axis by an amount *E*. The dimension 208 is equal to twice the eccentricity *E*, i.e. is equal to 2*E*; and the dimension 210 is equal to four times the eccentricity *E* i.e. is equal to 4*E*. If desired, the outer member may be driven by means of ring gear 212, or by any suitable means.

In operation, when the outer member grooves are four in number and the inner member lobes are three in number, then if the inner member speed is 1000 r.p.m. the outer member speed will be 750 r.p.m. and the relative speed between the members will be 250 r.p.m.

It is possible, therefore, to have a non-rotating outer member and rotating driven inner member, or a non-rotating inner member but driven and rotating outer member and an arrangement where both members are driven to rotate about their axes.

The direction of pumping may be reversed for a particular direction of rotation by providing outer and inner members of opposite hand.

WHAT WE CLAIM IS:—

1. A helical screw pump comprising an outer member and an inner member mounted sealingly within the outer member, the two members being mounted for relative rotation, the outer member having at least four internal helical grooves and the inner member having one less helical lobe, the said grooves being defined in any cross-section through the outer member perpendicular to the axis thereof by part-circular lobe arcs which have equal radii in a range from zero to a finite value, and the ratio of the diameter (*D*) of the circle hereinafter referred to as the " outer member scroll circle " through the radial centres of the lobe arcs in any cross-section through the outer member at right angles to the axis thereof to the eccentricity (*E*) of the inner member, the eccentricity being the distance that the inner member axis is offset from the outer member axis, being substantially equal to

$$\frac{16 \sin \frac{180^\circ n - 540^\circ}{2n(n-1)} \cdot \cos \frac{540^\circ}{2n} \cdot \sin \frac{360^\circ}{2(n-1)}}{\left(1 - \cos \frac{180^\circ}{n}\right) \cdot \left(1 - \cos \frac{180^\circ n - 540^\circ}{n-1}\right) - 4 \sin^2 \frac{180^\circ n - 540^\circ}{2n(n-1)}}$$

where n is the number of grooves in the outer member in order that the two members should rotate relatively to one another without jamming and without sealing contact between the said lobes and grooves being broken during rotation.

2. A helical screw pump according to claim 1, in which the cross-section of the space within the outer member at any point along its length is constant in shape, although varying in angular orientation about the outer member axis, the cross-section of the space being defined by a figure the periphery of which comprises lobe arcs having equal radii of a finite value and described from centres hereinafter called "lobe centres" within the cross-section and equiangularly spaced circumferentially on the outer member scroll circle and a corresponding number of intermediate part-circular arcs hereinafter called "blending arcs" joining the lobe arcs, the junctions of the lobe arcs and blending arcs being at positions of common tangents to the arcs, and described from centres outside the cross-section and equiangularly spaced around a circle concentric with the outer member scroll circle at positions angularly intermediate the lobe centres and in which the cross-section of the inner member at any point along its length is constant in shape, although varying in angular orientation about its axis, and being defined by a figure comprising the appropriate number of identical part-circular lobe arcs, i.e. one less than the number of lobe arcs of the outer member, but of the same radius as the outer member lobe arcs, described from centres within the inner member cross-section and equiangularly spaced around a circle hereinafter referred to as the "inner member scroll circle" having its centre on the axis of the inner member, and a corresponding number of part-circular blending arcs joining the inner member lobe arcs, the junctions of the latter and the inner member blending arcs being at positions of common tangents to the arcs, described from centres outside the inner member cross-section and equiangularly spaced around a circle concentric with the inner member scroll circle and passing through the centres on which said inner member lobe arcs are described at positions angularly intermediate such centres, the inner member scroll circle having a diameter which is equal to the outer member scroll circle diameter D less twice the eccentricity E i.e. inner member scroll circle diameter $= D - 2E$, the distance of the describing centres of the blending arcs of the outer member from the outer member axis being substantially equal to

$$\frac{2E\,(D-2E)}{4E-D\left(1-\cos\frac{180^\circ}{n}\right)}$$

where n has the same significance as before and the distance of the describing centres of the inner member blending arcs from the inner member axis being substantially equal to

$$\frac{2E\,(D-4E)}{6E-D+(D-2E)\cos\frac{180^\circ}{n-1}}$$

where n again has the same significance as before.

3. A helical screw pump according to claim 2, in which the outer member blending arcs are tangential to the outer member scroll circle, and in which the inner member blending arcs are tangential to the inner member scroll circle.

4. A helical screw pump according to claim 2, or claim 3 in which the outer member and inner member scroll circles are tangential to each other.

5. A helical screw pump according to any one of the preceding claims in which the number of outer member grooves lie within the range 4 to 8 inclusive.

6. A helical screw pump according to any one of the preceding claims in which the inner member or the outer member or both are made from resilient material such as rubber.

7. A helical screw pump according to any one of the preceding claims in which the outer member is mounted to rotate about its axis.

8. A helical screw pump according to claim 7, in which the outer member has drive means for driving connection to a rotary power input.

9. A helical screw pump substantially as described in the specification and as shown in the accompanying drawings.

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Leamington Spa: Printed for Her Majesty's Stationery Office, by the Courier Press (Leamington) Ltd.—1965. Published by The Patent Office, 25 Southampton Buildings, London, W.C.2, from which copies may be obtained.

1002642 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheets 1 & 2

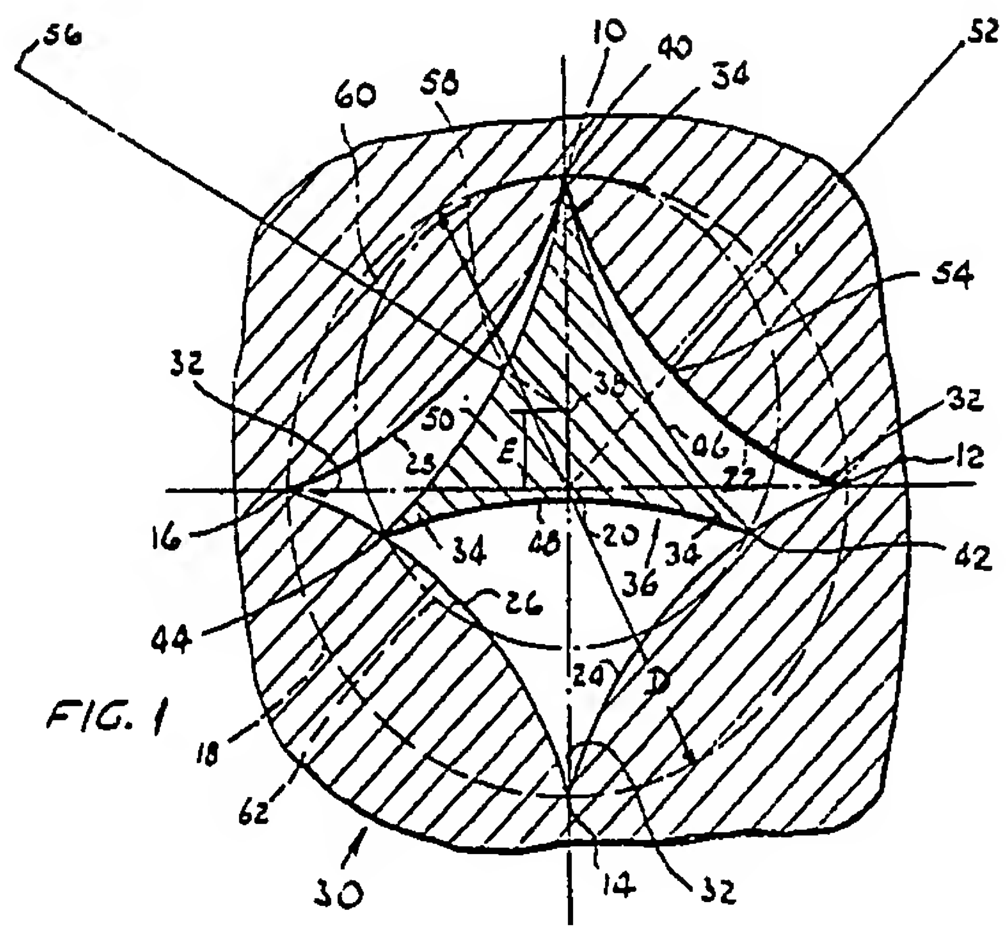

FIG. 1

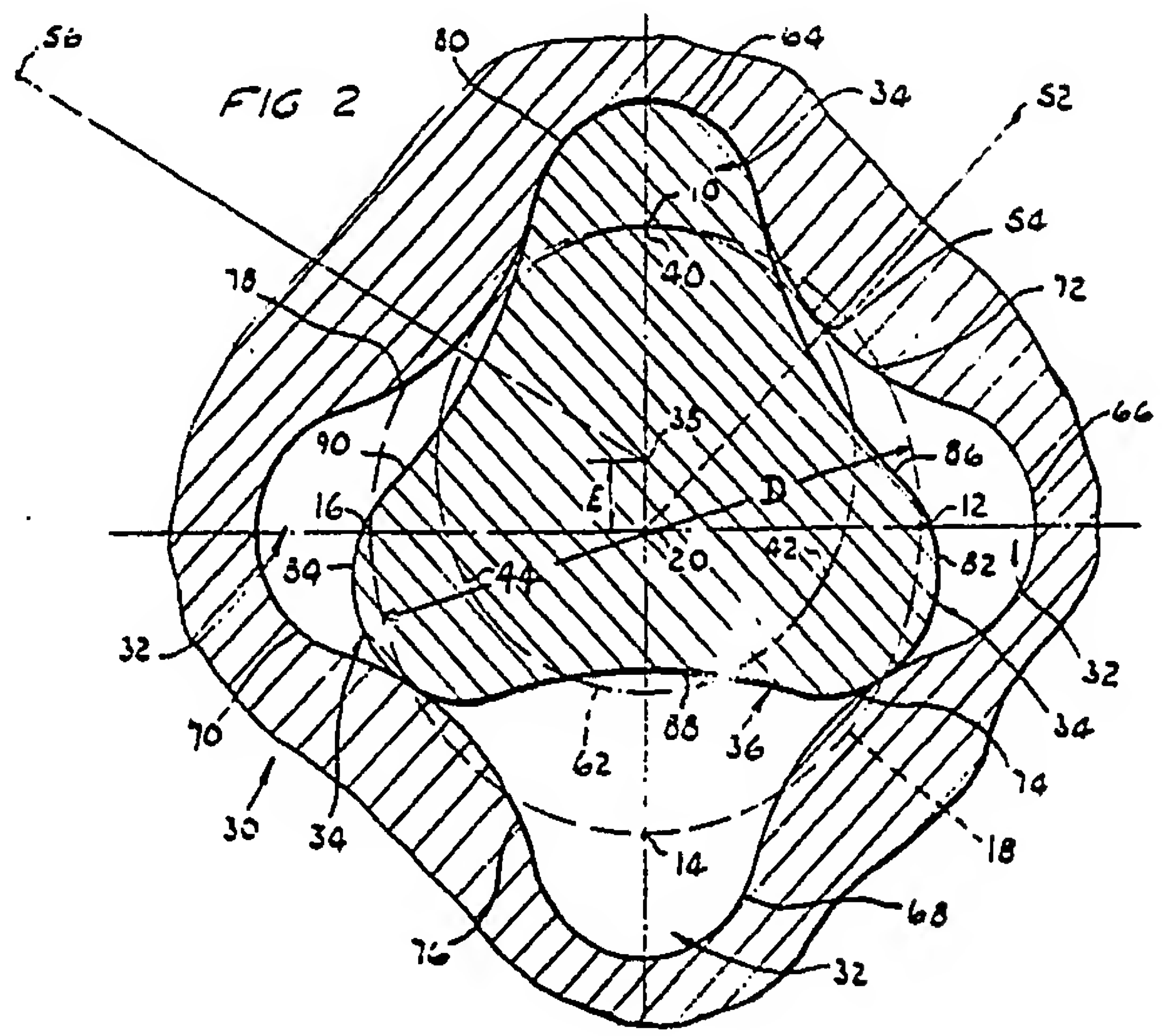

FIG 2

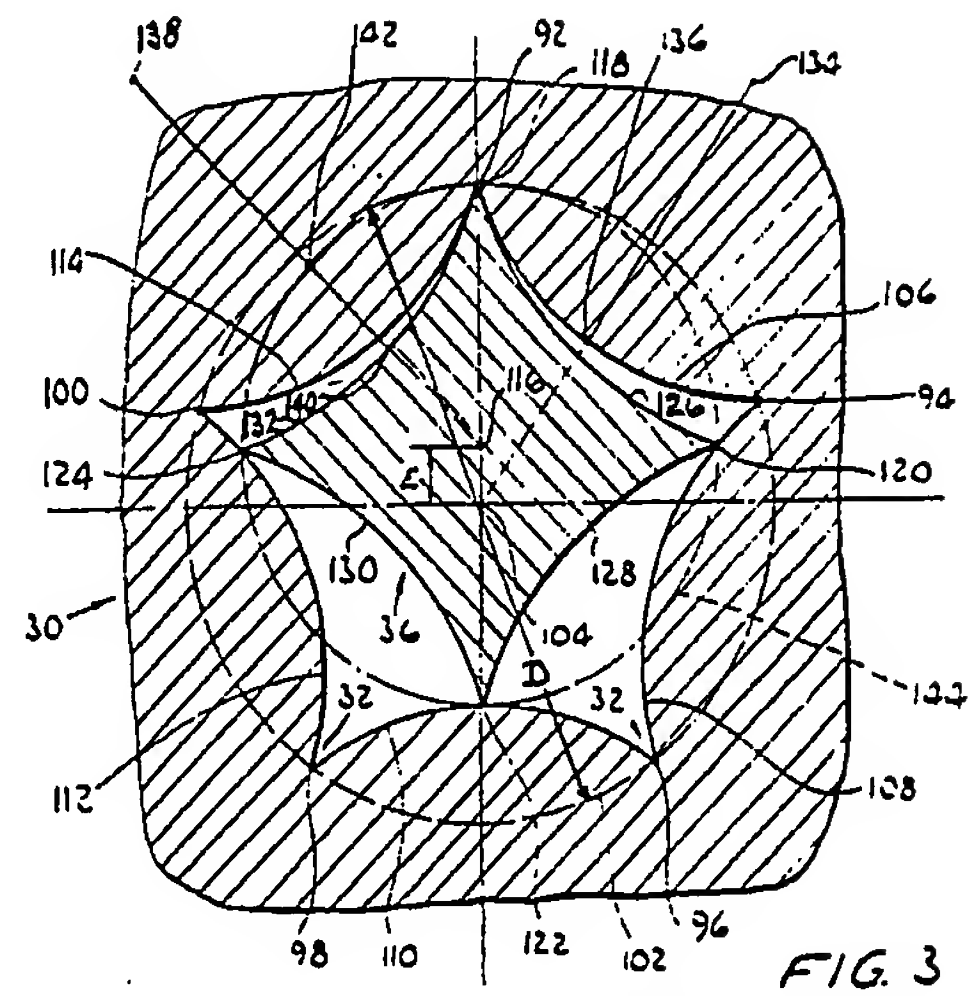

FIG. 3

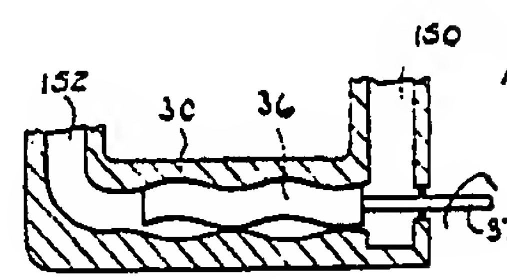

FIG. 4

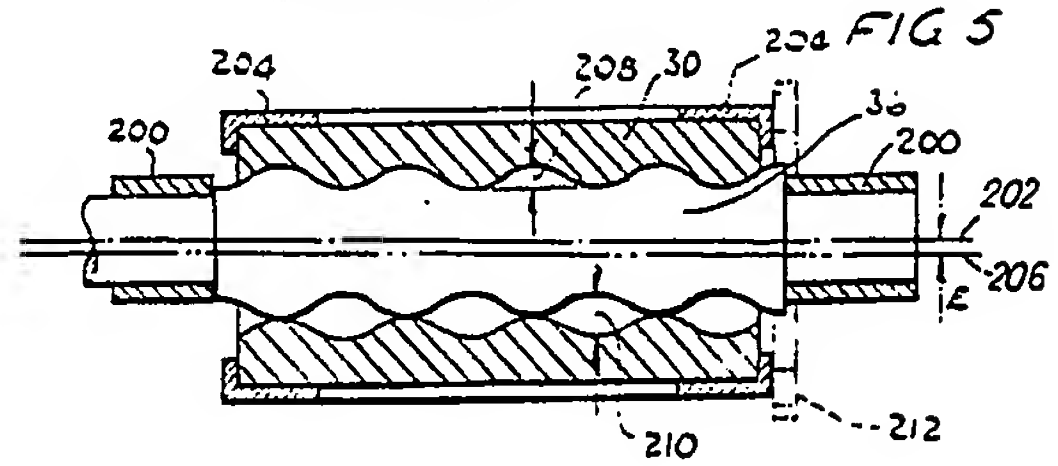

FIG 5